Evaluation of new proposals for the 2020 EIC Detector R&D Meeting

EIC Detector Advisory Committee

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Introduction

At the July 2017 meeting the EIC Detector Advisory Committee, anticipating a positive recommendation from the National Academy of Science with regard to the EIC project with an associated significant increase in new proposals, adopted a new review procedure to make the committee meeting and overall review process more efficient. The new procedure calls for new proposals to be submitted 8 weeks before the EIC advisory meeting and to be pre-screened, with feedback provided to the proponents 30 days before the plenary committee meeting. No change to the procedure for on-going projects was proposed.

General Assessment

Four new proposals were received for the 2020 Summer EIC Detector R&D Meeting. The level of detail varied between the pre-proposals but sufficient information was provided to evaluate the proposals to proceed to submission of a full proposal and presentation at the in-person meeting or not. This report summarizes the evaluation of the committee of the four proposals.

Proposal Evaluation

Proposal 1: Superconducting Nanowire Detectors for the Electron Ion Collider (W. Armstrong, ANL)

The proposal is to qualify superconducting nanowire detectors for applications at the Electron Ion Collider. Nanowire detectors are relatively novel superconducting devices for measuring individual photons in the 1,000 to 2,000 nm range with excellent timing resolution, high spatial precision and low noise. They have been shown to work well in high magnetic fields and under high radiation doses. The T_C for the sensors already fabricated at ANL seems to be on the order of a few degrees K (Fig. 5 in the proposal). The proposal mentions 10x10 μm^2 to 20x20 μm^2 pixels but allows that pixels can be operated in parallel with a loss in signal amplitude and rise time. The timing precision is expected to be fundamentally limited at about 3 ps. The plan of work is to test whether such sensors could be used for charged particles.

<u>Evaluation</u>:
While the proposal notes that high spatial and temporal precision will be needed for an EIC detector, there is no description of how a realizable nanowire detector might be implemented. For pixel sizes of order the ten or twenty μm^2 mentioned in the proposal, the number of conductor penetrations from the cryogenic environment to some warmer regime is very large indeed. The heat leak from such a large cable plant would seem to be overwhelming even if the cable plant itself were feasible. Even the smallest EIC sub-detector will need many square centimeters of sensitive area which seems difficult to realize both physically and thermally given the need to get signals from the nanowire detectors to electronics in the warm (since as the proposal notes, electron mobility in silicon or other semiconducting materials goes to zero at these very low temperatures).

<u>Recommendation</u>:
The committee would welcome the submission of a more complete proposal that, in addition to the information already provided, outlines one or more plausible methods that might allow the construction of a full-scale EIC detector sub-system using nanowire elements given the apparently overwhelming thermal and cabling challenges.

Proposal 2: Developing a High Resolution ZDC for the EIC

The design of a high-resolution, position-sensitive Zero Degree Calorimeter (ZDC) is proposed to measure neutrons and photons at the EIC. The proponents already made a strong case at the January 2020 EIC detector R&D meeting for the physics value of a zero-degree calorimeter at the EIC to measure the gluon saturation at extreme density through a set of diffractive processes and exclusive vector-meson production in e-A collisions. The requirements to access this physics is a calorimeter at very small angles to accurately measure energies of photons below 300 MeV and fully measure the energy of neutrons up to 100 GeV. A total absorption calorimeter is needed with about 1cm position resolution and $50\%/\sqrt{E}$ energy resolution. The proposal seeks to develop a realistic detector configuration that can deliver the performance needed for the EIC physics goal. The study will rely heavily on the tools for design and simulation that have been developed already by Jefferson Lab and BNL.

<u>Evaluation</u>:
The proponents seek to exploit both Cherenkov light and scintillation light to obtain the best energy and position resolution for the detection of photons and neutrons in the far forward region. Several interesting techniques are being proposed, such as a plastic scintillator or crystal calorimeter, a quartz fiber calorimeter or an imaging silicon calorimeter such as the forward calorimeter (FoCal) that has been proposed for Run 4 for the ALICE experiment. The photon energies are relatively low, less than 1 GeV. The ZDC aperture will be studied for maximal detection acceptance. The number of spectator neutrons is expected to be correlated with the collision geometry. BeAGLE will be used for acceptance simulations. The calorimeter is required to distinguish somewhere between 20 and 30 neutrons and have sensitivity to a MIP signal. Maintaining the energy resolution after irradiation is a key requirement. Simulation studies using the G4E framework has started. Integration of BeAGLE into the simulation framework will be carried out to study the simultaneous detection of soft photons (~300 MeV) and neutrons with the beam energy. The key deliverables of the project are the integration of the simulation tools and the optimization of the geometry, both within the accelerator context and the detector geometry. Radiation dose estimates will be refined, and tests of prototype detectors will be carried out.

<u>Recommendation</u>:
The committee very much welcomes submission of the full proposal. The physics clearly motivates the research proposed. The project has a broad scope and a relatively small budget and seems to depend on efforts that are outside of the scope of this proposal (see Table 1 in the proposal). It would be appreciated if these external dependencies can be addressed during the meeting and what the internal dependencies are. For example, how does the FoCal R&D at RIKEN depend on elements of this proposal and vice versa.

Proposal 3: Proposal for a pulsed laser system for Compton polarimetry at the future EIC facility (C. Gal)

The authors propose development of a 10W pulsed laser system to use as the source of photons that are used to measure electron bunch mean polarization via Compton scattering. Earlier projects presented to the Committee addressed expected analyzing powers for Compton scattering for the expected electron beam energies at an electron-ion collider and the measurement times that would result for various assumed laser powers and beam parameters with a goal of a one percent measurement of electron beam polarization. Discussion among the EIC user community has led to a goal to measure electron beam polarization on a bunch-by-bunch basis. This would need to be done on a timescale shorter than the average bunch lifetime. This also leads to a need to time-resolve the electron bunches, which pass a typical interaction region at 25 or 100 MHz, depending on electron beam energy in the current EIC design.

Evaluation:
The authors propose to develop a 10 W pulsed laser, initially of 1064nm wavelength, later to be halved to 532nm to improve the scattering kinematics. The Committee assumes the pulsed character is to concentrate the laser power at the appropriate time when the electron beam transits. This does lead to different requirements on the laser time-structure than e.g. used at JLab for the Compton-scattering polarimeters due to the quasi-CW nature of the JLab electron beam. The proposal addresses needed photon beam parameters, electron-photon luminosity, expected asymmetries, and the measurement time to reach a one percent measurement. The times quoted are indeed smaller than the projected bunch lifetimes for EIC but not by a large factor. The design appears to aim for at most one scattered electron per bunch crossing to as not to complicate the measurement.

The need for good electron polarimetry is acknowledged. Development of an adequate laser system would seem to be a good investment in order to allow design and construction of the needed Compton polarimeter on the timescale for initial EIC experiments. An expanded description of the proposed laser system, with more justification for the various expenditures, is needed. The labor appears to be fully supplied by the collaborating institutions, which have a good base of experience with the needed system.

Recommendation:
It is recommended that this proposal proceed to full proposal submission. The authors are asked to discuss the required speed, count rate capability and spatial segmentation of the electron detector that would also need to be deployed; a discussion of likely technology choice(s) for this detector would also be welcome. The authors are also asked to provide larger-scale graphs, or at least graphs with markedly larger font size, to compensate for the deteriorating eyesight of the ever-aging reviewers.

Proposal 4: Precision Timing Silicon Detectors for a Combined PID and Tracking System at the EIC (W. Li)

The proposal "Precision Timing Silicon Detectors for a Combined PID and Tracking System at the EIC" targets studying the feasibility of combined Time Of Flight and tracking in an EIC detector by applying fast timing techniques such as LGADs. The proponents are involved in the CMS end cap MIP timing detector and propose to leverage that expertise for an optimization study of the timing and position resolution of LGADs sensors to meet the requirements of a compact TOF-tracker system at the EIC. A systematic study of the performance of thin LGADs combined with detailed simulations to determine the position resolution for a tracking system is proposed.

Evaluation:
The proposal leverages experience and technology developed as part of the CMS Phase-2 upgrade project. There are three parts to the proposal. The first part focused on the R&D of ultra-thin LGAD sensors. The sensors will be obtained through existing collaborations. Timing resolutions of 15 -20 ps are targeted, possible through test beam measurements at Fermilab. The second part addresses the simulation of a combined TOF-Tracker system. The last element of the one-year proposal is the study of LGAD devices with AC-coupling and trench isolation. AC-LGAD devices obtained from both FBK and BNL will be studied and TI-LGADs from FBK are in hand. Although this project aims at a combined TOF and tracking system, we note the technical complementarity with the already approved EIC R&D effort to apply LGADs in far forward Roman Pot stations (eRD24). We also note that there is technical overlap, particularly in the area of position resolution, AC-LGADs, and system issues. This is a modest proposal and as stated, leverages

considerable advantages from the CMS experience. A broad and strong team is in place to carry out the work.

<u>Recommendation:</u>
Submission of a full proposal is strongly welcomed. The proponents are kindly asked to provide more information in the full proposal on the following aspects:

- *Elaborate on the reach in particle identification for the proposed tracker-TOF system and the complementarity with the current proposed PID detectors.*
- *Expand on how the goal of 10-15 ps timing resolution will be obtained using MIP particles with real electronics.*
- *Discuss the technical requirements needed for the test beam setup to reach a timing resolution of 10 to 15 ps as well as the feasibility of satisfying those requirements.*
- *If not too early, address the mechanical aspects of the implementation of ultra-thin LGAD detectors for a tracker application covering multiple square meters of area.*
- *Elaborate on the collaboration with eRD24 and BNL.*